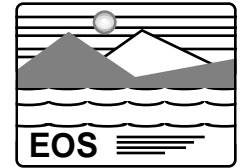




EOS AM-1 Mission Operations Review



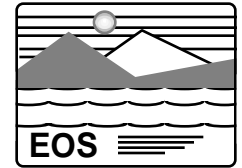
FLIGHT DYNAMICS

**LAURI KRAFT NEWMAN
AND
MARK WOODARD**

**Goddard Space Flight Center
Greenbelt, MD 20771 USA**



EOS AM-1 Mission Operations Review



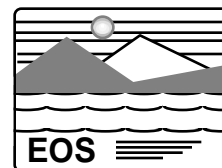
ORBIT (MANEUVER AND NAVIGATION)

LAURI KRAFT NEWMAN
Flight Dynamics Division

Goddard Space Flight Center/Code 552
Greenbelt, MD 20771 USA
E-mail: lauri.newman@gsfc.nasa.gov



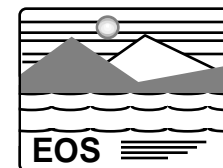
Mission Overview



- **Launch: June 1998 (duration: 5 year; goal: 6 years)**
- **Launch vehicle: Atlas II AS**
- **Orbit**
 - **Frozen**
 - **Sun-synchronous, 98.2-degree inclination**
 - **Repeat cycle: 233 revolutions per 16 days**
 - **705-km mean altitude over Equator**
 - **10:30 a.m. (± 15 minutes) descending node mean local time (MLT)**
 - **± 20 -km ground track control at Equator**
 - **$+10/-5$ -km radial constraint**



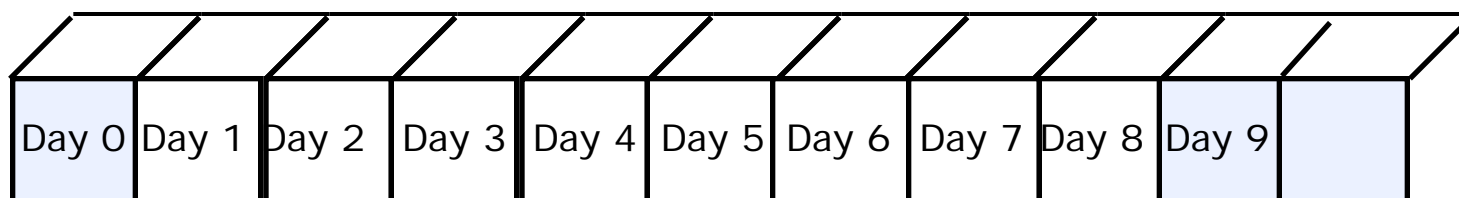
Launch/Acquisition Phase Operations



Prelaunch
Phase
Days: Pre 1

Launch/
Acquisition
Phase
Days: 1 - 9

Checkout
Phase
Days 9=>



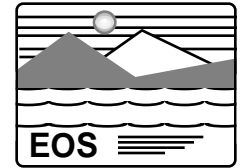
Early Mission Operation Day 1 Rev 0
Go to Internal Power (L-5:00)
Liftoff (L)
Fairing Jettison (L+3:12)
S-Band Transmitter On (L+7:00)
Launch Vehicle Separation (L+14:00)
Earth Acquisition (L+14:00 - 30:00)
MOPITT Power Commands (L + 15:00)
Solar Array Deployment (L + 16:00 - 32:00)
Command Link Establishment (L + 24:00)
HGA/Instrument Power Commands (L+35:00)
Array Rotation Commanding (L+ 58:00)

Orbit Acquisition: Days 4 - 9
Orbit Acquisition Burns
Trim Maneuvers
Achieve Mission Orbit

Transfer Orbit Operations Days 1 -3
MODIS Power Enabled
HGA Deployment
HGA Gimbal Checkout
HGA Communications Check out
Playback Launch Ascent Telemetry
Propellant Gauging
Orbit elements and stored commands for HGA pointing



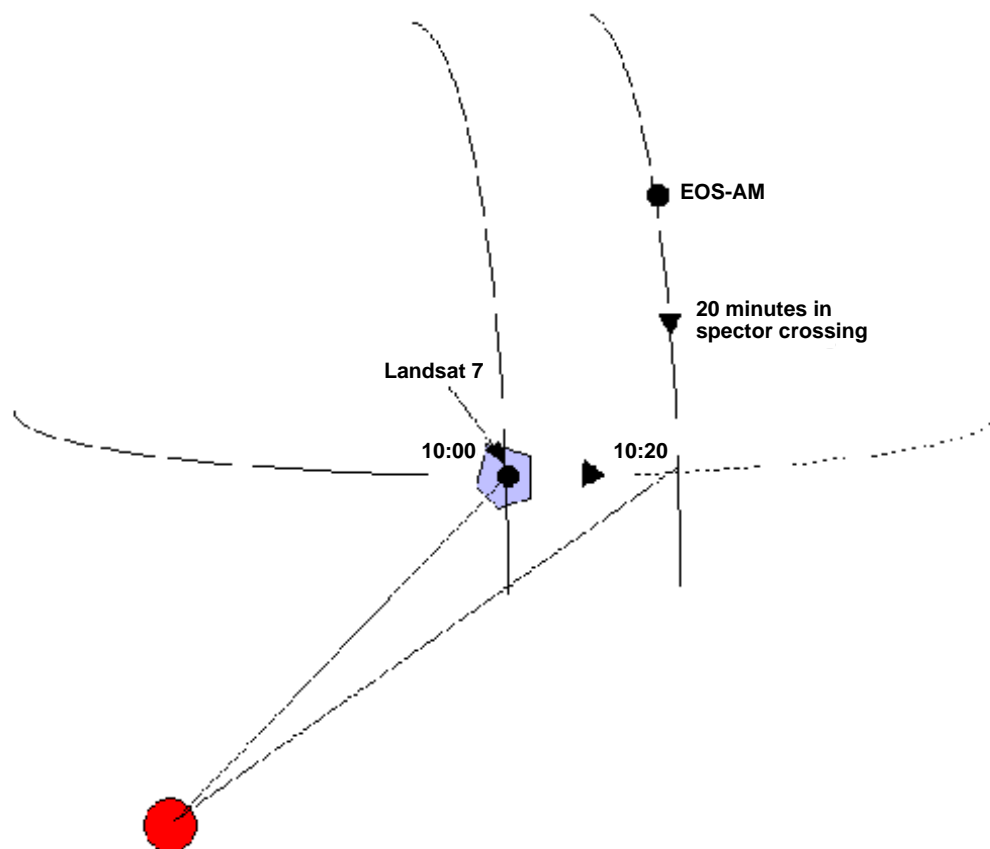
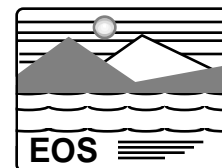
Constellation Flying With Landsat 7



- **Interproject Agreement (IPA) between AM-1 and Landsat 7 signed in April 1996**
- **Agreement to fly same ground track such that both spacecraft view the same area within 15 minutes to 1 hour (as close to 15 minutes as possible)**
- **Separation within orbit required to fly same ground track is dictated by orbit plane MLT separation**
- **MLT separation is determined by launch times**
- **Impacts timing of ascent maneuvers**
- **All active constellation maintenance will be performed by Landsat 7**
- **No impact to EOS AM-1 fuel budget**

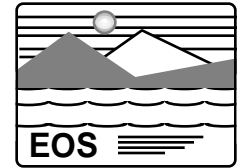


Constellation Flying With Landsat 7 (Cont'd)





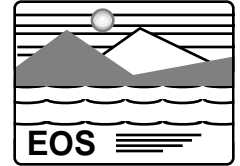
EOS AM-1 Launch



- **Launch window**
 - **Daily opportunity**
 - **Approximately 20-minute window each day**
 - **Atlas II AS guidance capabilities allow optimizing inclination for launch time to eliminate inclination maintenance**
- **Higher transfer orbit due to performance margin release**
 - **As spacecraft mass matures, final transfer orbit altitude will be determined; current estimate is perigee height of 650 km, although current baseline is 550 km**
 - **Higher transfer orbit means fewer opportunities to synch up with Landsat-7 during spacecraft checkout period**



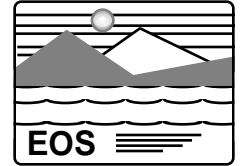
Maneuver Plan



- **Plan to perform ground track maintenance maneuvers periodically**
 - As frequently as once every 2 weeks for high solar flux
 - As infrequently as once every 6 months for low solar flux
- **Not expecting to perform inclination maintenance**
 - Fuel budget includes removing Atlas II AS dispersions plus one maneuver at end of life (EOL) in case mission is extended
 - Initial inclination will be chosen to allow MLT to remain within 10:30 \pm 15-minute control box throughout mission lifetime



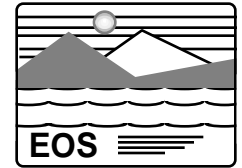
Orbit Determination



- Using TONS
- Orbit solution comes down in telemetry in science and housekeeping packets
- Small gaps in data will be repaired by Science Data Processing Segment (SDPS) using Flight Dynamics Division (FDD)-supplied algorithm
- Large gaps will be definitively filled by FDD on request
- Position knowledge requirement is 150 meters per axis, 3σ
- Actual performance expected to be 5 to 10 meters, 1σ
 - Based on new analysis (previous expectation was 20 meters)
 - Assumes no solar storms



EOS AM-1 Mission Operations Review



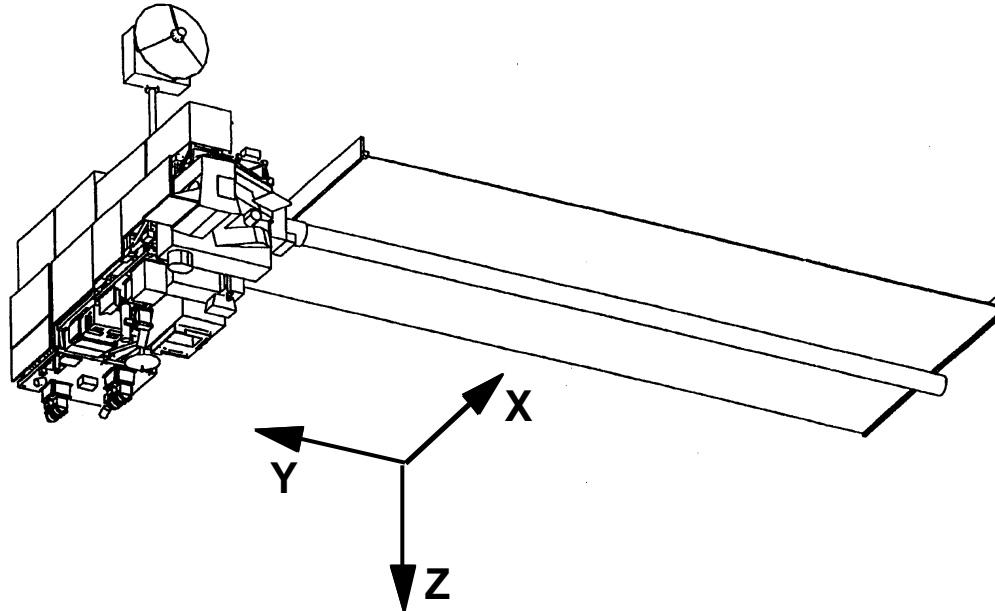
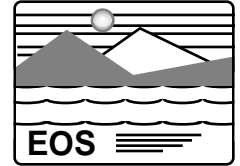
ATTITUDE

MARK WOODARD
Flight Dynamics Division

Goddard Space Flight Center/Code 552
Greenbelt, MD 20771 USA
E-mail: mark.woodard@gsfc.nasa.gov



Attitude Orientation

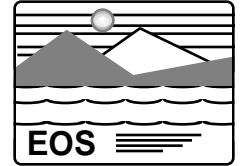


Nominally, the spacecraft is aligned with the local vertical, local horizontal (LVLH) frame:

- **Y is along the negative orbit normal vector**
- **Z is along nadir vector**
- **X is defined to complete the right-hand coordinated system**



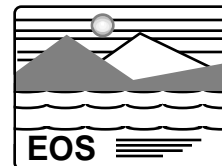
Sensors



- **One Inertial Reference Unit (IRU)**
- **Two Three-Axis Magnetometers (TAMs)**
- **Two Earth Sensor Assemblies (ESAs)**
- **One Fine Sun Sensor (FSS)**
- **Two Solid State Star Trackers (SSSTs)**
- **One Coarse Sun Sensor (CSS) Assembly**



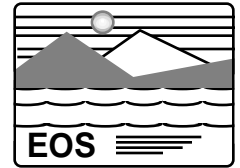
Star Catalog



- **SKYMAP Master Catalog will be used to generate EOS AM-1 mission catalog**
- **Star selection criteria still being worked with Lockheed Martin, McDonnell Douglas Astronautics (MDA)**
- **Final mission catalog will consist of approximately 700 “equally distributed” stars**
- **FDD plans to deliver initial star catalog last quarter CY96**



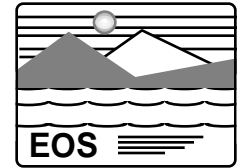
Star Selection Criteria



- Instrumental magnitudes between 2.0 and 5.7
- No stars included with proper motion greater than 0.7 arc-second per year
- No stars included with position uncertainty greater than 0.6 arc-second
- “Near-neighbor” stars will be flagged



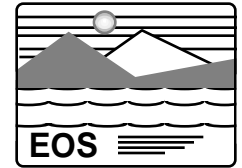
Attitude Maneuver Plan



- **Attitude maneuvers will be required during L&EO for**
 - **Instrument calibration**
 - **IRU calibration**
 - **FSS field of view calibration**
- **Additional maneuvers may be required during normal mission phase to maintain attitude determination requirements**
- **Detailed maneuver timeline will be worked with project and FOT personnel**



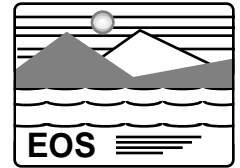
Sensor Calibration Plan



- **Calibration includes**
 - **SSST alignment matrixes and scale factors**
 - **FSS alignment matrix and field of view (FOV) calibration parameters**
 - **IRU alignment matrix and scale factors**
- **Preliminary calibration handbook available end of 1997**



EOS AM-1 Mission Operations Review



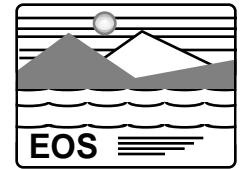
FLIGHT DYNAMICS SYSTEMS AND OPERATIONS CONCEPT

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Greenbelt, MD 20771 USA
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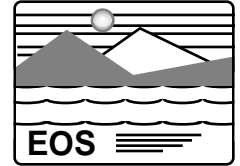
L&EO Operations Concept



- **FDD personnel provide support until early spacecraft checkout complete**
 - Maneuver planning and calibration
 - Orbit determination and TONS checkout
 - Attitude determination and verification
 - Star catalog update, if needed
 - Sensor calibration
 - Product generation
- **Support provided from Flight Dynamics Facility (FDF) in Building 28**
- **Support will be 24 hours during critical periods**
- **Liaison personnel will be available in EOC to operate FDD workstations and train FOT**



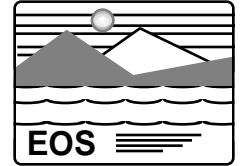
L&EO Operations Concept



- **FDD hands over all functions to FOT or Code 500 support contractor after spacecraft checkout**
- **FDD will provide**
 - **Necessary software and hardware**
 - **Training to FOT**
 - **Documentation of procedures and system operation**



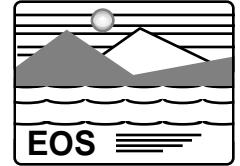
Routine Operations



- FOT provides routine operations support
- FDD on call for contingency, anomaly resolution, and special operations



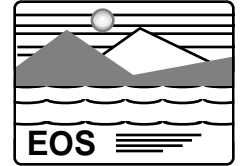
Staffing Plan



- **L&EO**
 - Two 12-hour operations shifts
 - Prime shift (centered around orbit and attitude maneuvers)
 - » In EOC: one products engineer
 - » In Flight Dynamics Operations Area: one lead attitude engineer, one attitude engineer, one lead orbit engineer, one orbit engineer, two OD engineers
 - Off shift
 - » In EOC: one attitude engineer, one orbit engineer
- **Routine operations**
 - Staffing provided by FOT
 - Maneuver planning, TONS monitoring, and master oscillator monitoring provided by Code 500 contractor support
 - FDD will provide consultation on request



FDD System Concept

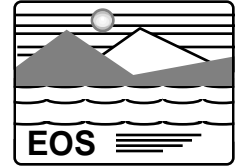


Interfaces

- **EOC (Bldg 32)**
 - All Flight Dynamics deliverables made available to EOC
 - Telemetry from EOC made available to FDD
- **FDD (Bldg 28)**
 - Code 500 contractor support tasks
 - L&EO support



FDD System Concept (Cont'd)

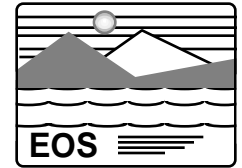


Interfaces (cont'd)

- **FOT**
 - Responsible for all Flight Dynamics functions in EOC after spacecraft checkout
 - Flight Dynamics personnel responsible for training FOT personnel during prelaunch and early mission phases
- **SDPS**
 - Repaired orbit data, as needed



FDD System Concept (Cont'd)

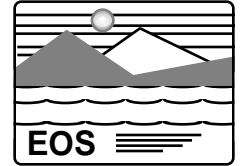


Support Hardware in EOC

- Two Hewlett-Packard UNIX workstations
 - One prime; one backup
 - Products: Real-Time Attitude Determination System (RTADS), Attitude Determination System (ADS), calibration, planning products, quality assurance (QA) tool
- Two Sun UNIX workstations
 - One prime; one backup
 - Product: TONS Ground Support System (TGSS)
- Two Pentium Pro PCs with Windows NT
 - One prime; one backup
 - Products: maneuver planning, ephemeris generation
- Cabling connectivity within EOC (Bldg 32)



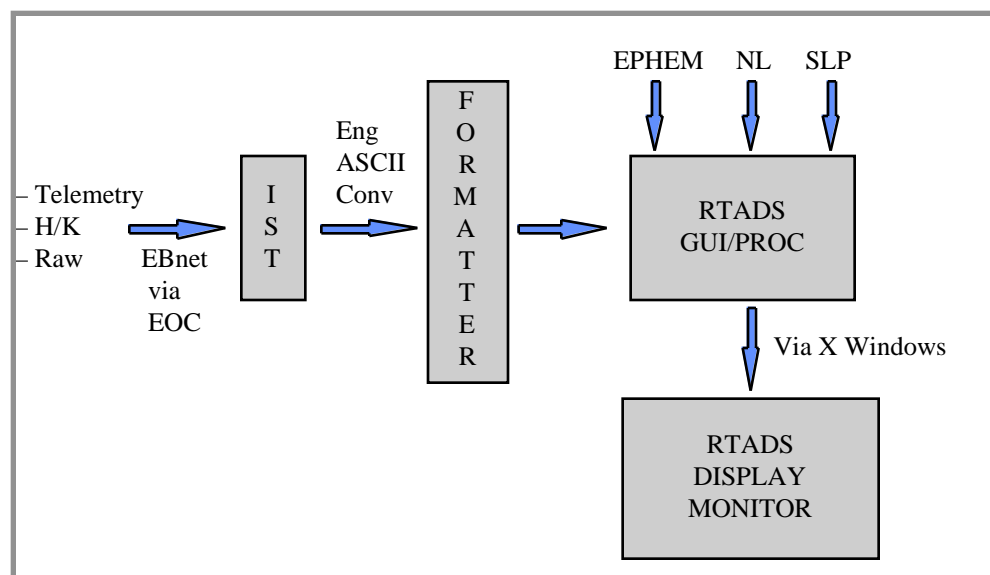
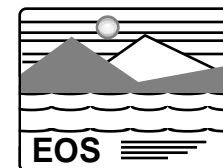
Contractor Interfaces



- **FDD will perform the following functions via Code 500 contractor tasks:**
 - **Launch vehicle support**
 - **Tracking data evaluation and local oscillator frequency calculations**
 - **Star catalog generation**
 - **On-orbit maneuver support**
 - **Sensor calibrations**
 - **TDRS orbit determination**
 - **Spacecraft orbit determination before TONS is operational**



Operational Scenarios: Real-Time Attitude



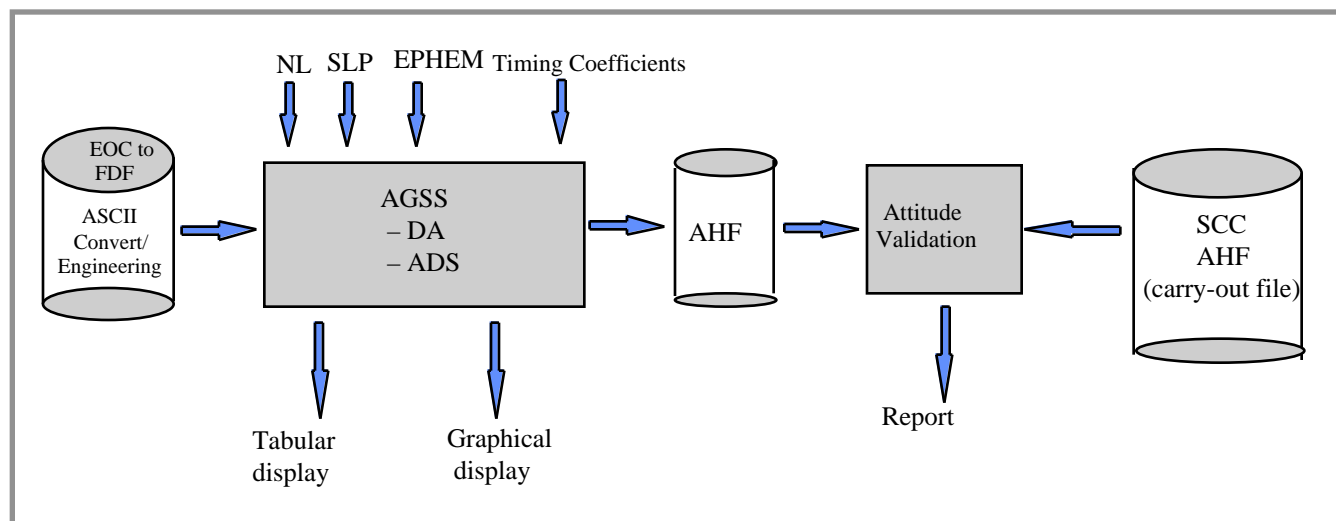
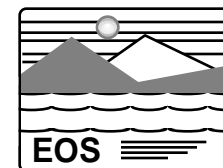
Legend:

AHF – attitude history file
EOC – EOS Operations Center
FDF – Flight Dynamics Facility
FOT – Flight Operations Team
GUI – graphical user interface
H/K – housekeeping
IST – Instrument Support Terminal
NL – namelist
OBC – onboard computer
SLP – solar/lunar/planetary

Performed by FDD during L&EO
and by FOT during routine operations



Operational Scenarios: Offline Attitude Validation



Legend:

ADS – Attitude Determination System
AGSS – Attitude Ground Support System
AHF – attitude history file
DA – data adjuster
EOC – EOS Operations Center
FDF – Flight Dynamics Facility
NL – namelist
SCC – spacecraft control computer
SLP – solar/lunar/planetary

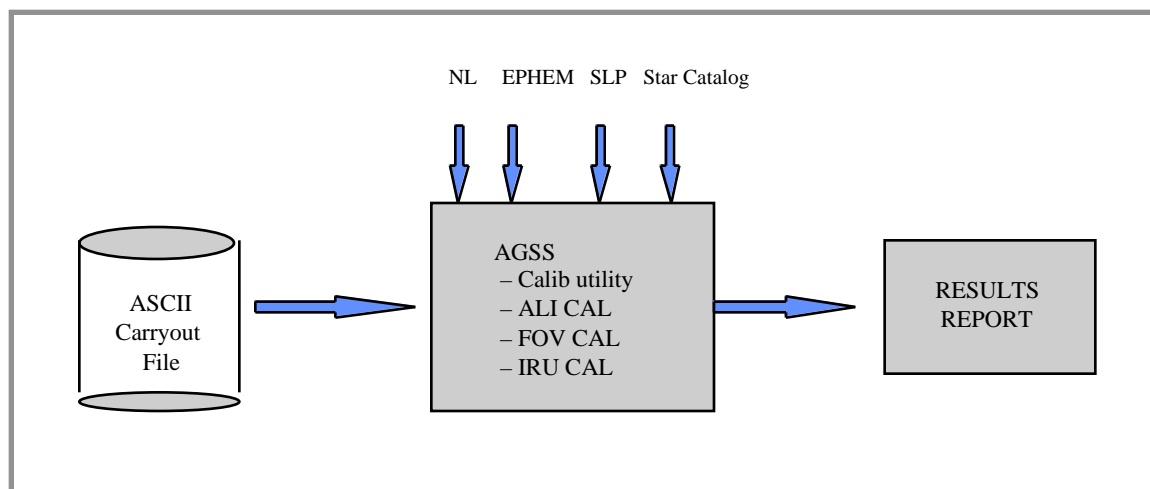
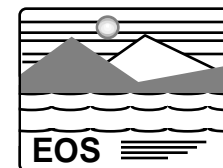
Files from IST for non-real-time data:

- Carry out format
- Standing order request of FOT
- FOT generate
- Frequency set by FDF
- Content/mnemonics set by FDF

Performed by FDD during L&EO
and by FOT during routine
operations for contingencies
(automated process)



Operational Scenarios: Attitude Calibration



Legend:

AGSS – Attitude Ground Support System

ALI – alignment

CAL – calibration

FOV – field of view

IRU – inertial reference unit

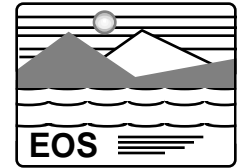
NL – namelist

SLP – solar/lunar/planetary

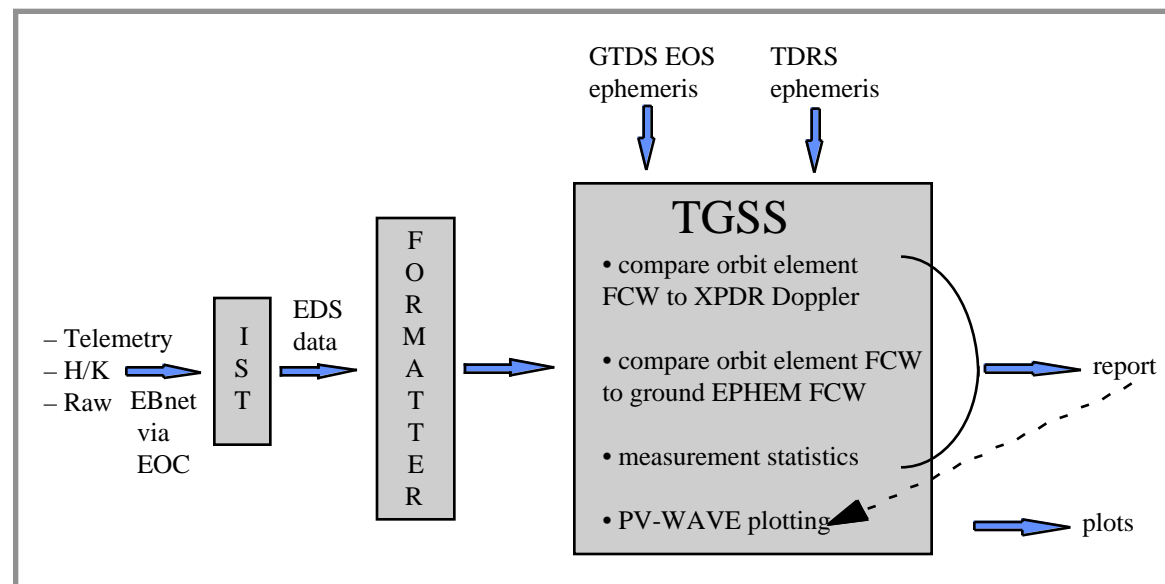
Performed by FDD during L&EO
and by FDD and Code 500 contractor
during routine operations (no FOT
requirement)



Operational Scenarios: Orbit (TONS)



TGSS Sequence Prior to TONS Initialization *(Orbit Elements Frequency Control Word & Doppler Evaluation)*



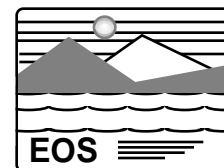
Legend:

EDS – engineering data set
EOC – EOS Operations Center
FCW – frequency control word
GTDS – Goddard Trajectory Determination System
H/K – housekeeping
TDRS – Tracking and Data Relay Satellite
TGSS – TONS Ground Support System
TONS – TDRSS Onboard Navigation System
XDPR – transponder
10034213W

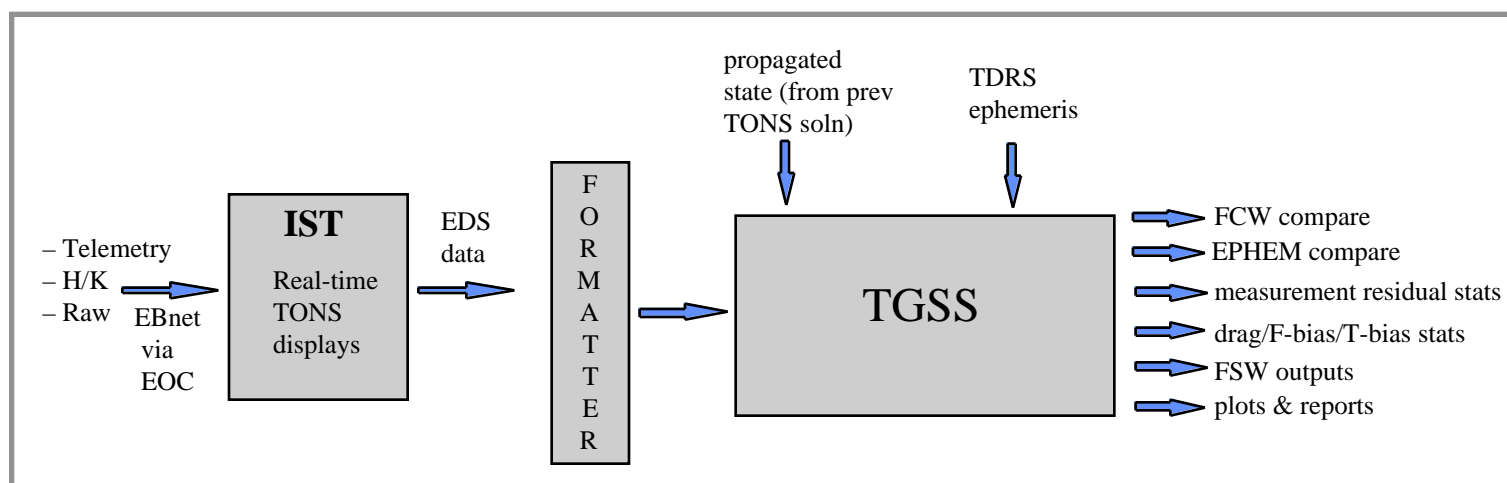
Performed by FDD during L&EO and
by FDD contractor during contingencies
(no FOT requirement)



Operational Scenarios: Orbit (TONS) (Cont'd)



TGSS Sequence After TONS Initialization (TONS Performance Evaluation)



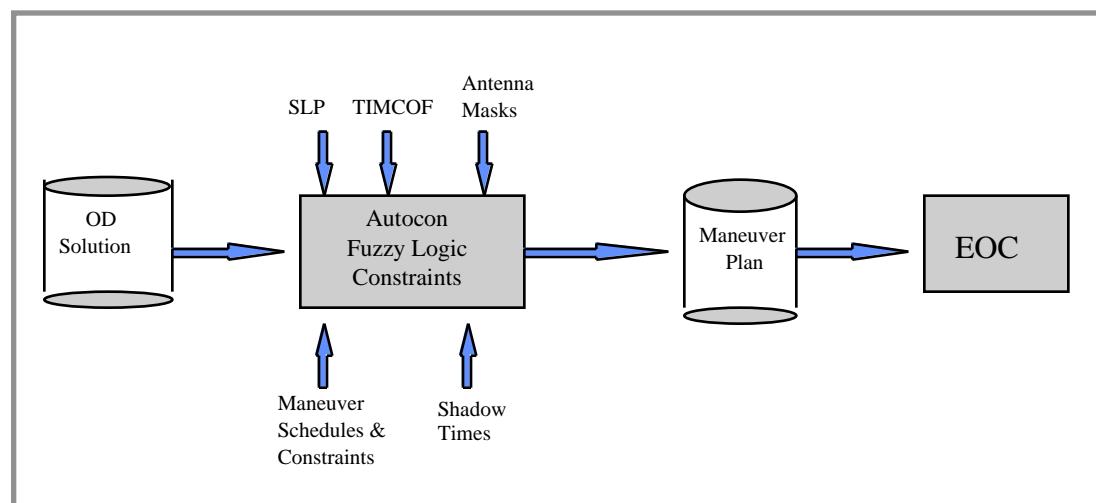
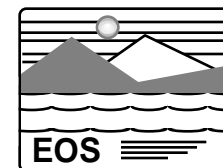
Legend:

EDS – engineering data set
EOC – EOS Operations Center
FCW – frequency control word
FSW – flight software
GTDS – Goddard Trajectory Determination System
H/K – housekeeping
IST – Instrument Support Terminal
TDRS – Tracking and Data Relay Satellite
TGSS – TONS Ground Support System
TONS – TDRSS Onboard Navigation System

Performed by FDD during L&EO
and by FDD contractor during
routine operations (no FOT
requirement)



Operational Scenarios: Maneuver Planning



Legend:

EOC – EOS Operations Center

OD – orbit determination

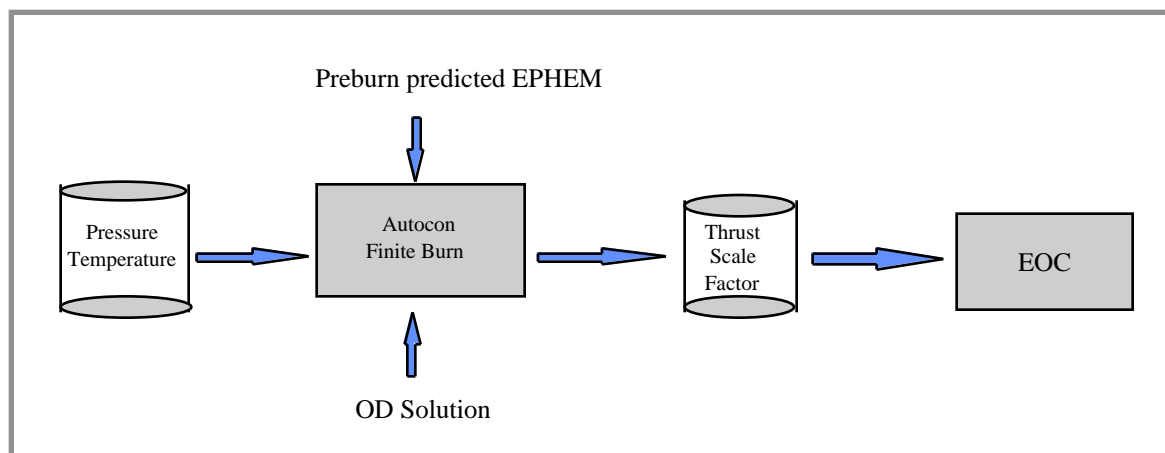
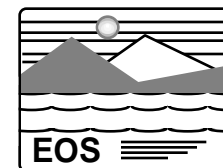
SLP – solar/lunar/planetary

TIMCOF – time coefficient

Performed by FDD during L&EO and
by FDD contractor during routine
operations



Operational Scenarios: Maneuver Calibration



Legend:

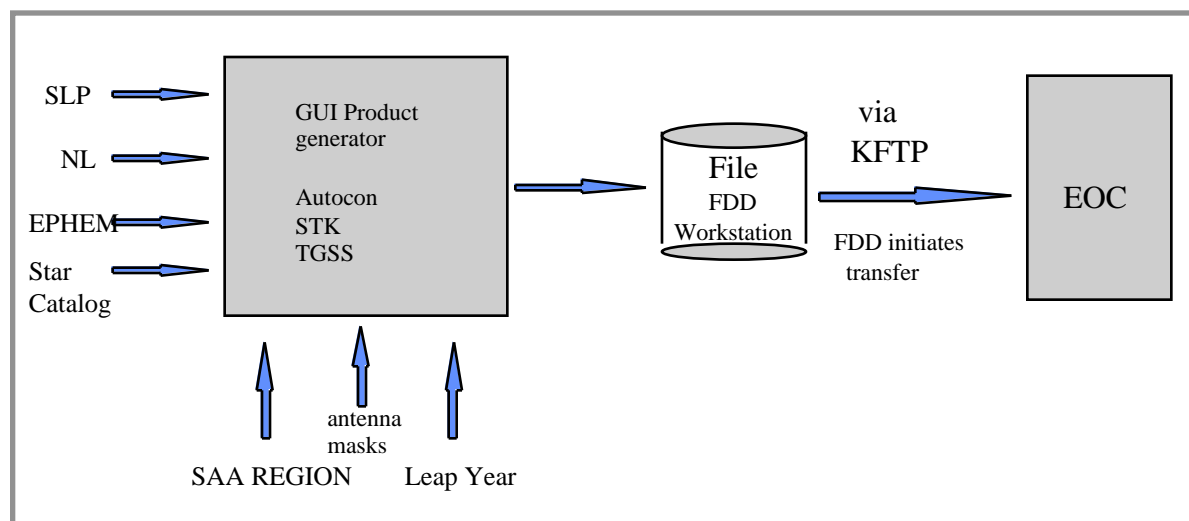
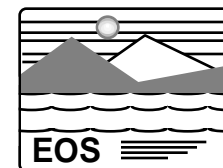
EOC – EOS Operations Center

OD – orbit determination

Performed by FDD during L&EO and by
FDD contractor during routine operations



Operational Scenarios: Product Generation



Legend:

EOC – EOS Operation Center

GUI – graphical user interface

KFTP – Kerberos File Transfer Protocol

NL – namelist

SAA – South Atlantic Anomaly

SLP – solar/lunar/planetary

STK – satellite toolkit

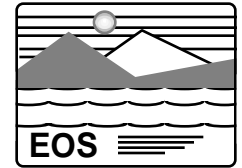
TGSS – TONS Ground Support System

TONS – TDRSS Onboard Navigation System

Performed by FDD during L&EO
and by FOT during routine operations



Detailed Mission Requirements (DMR) Compliance

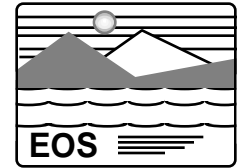


All requirements will be met

- **Orbit software**
 - Evaluation software for onboard navigation
 - Tracking data preprocessor
- **Maneuver software**
 - Maneuver planning
 - Orbit prediction
- **Attitude determination software**
 - RTADS
 - ADS
 - Calibrator
- **Mission planning product generation software**
 - Mission planning and scheduling products
 - Interference and visibility predictions
 - Acquisition data generation



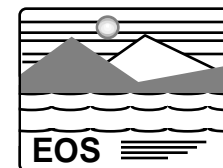
EOS AM-1 Mission Operations Review



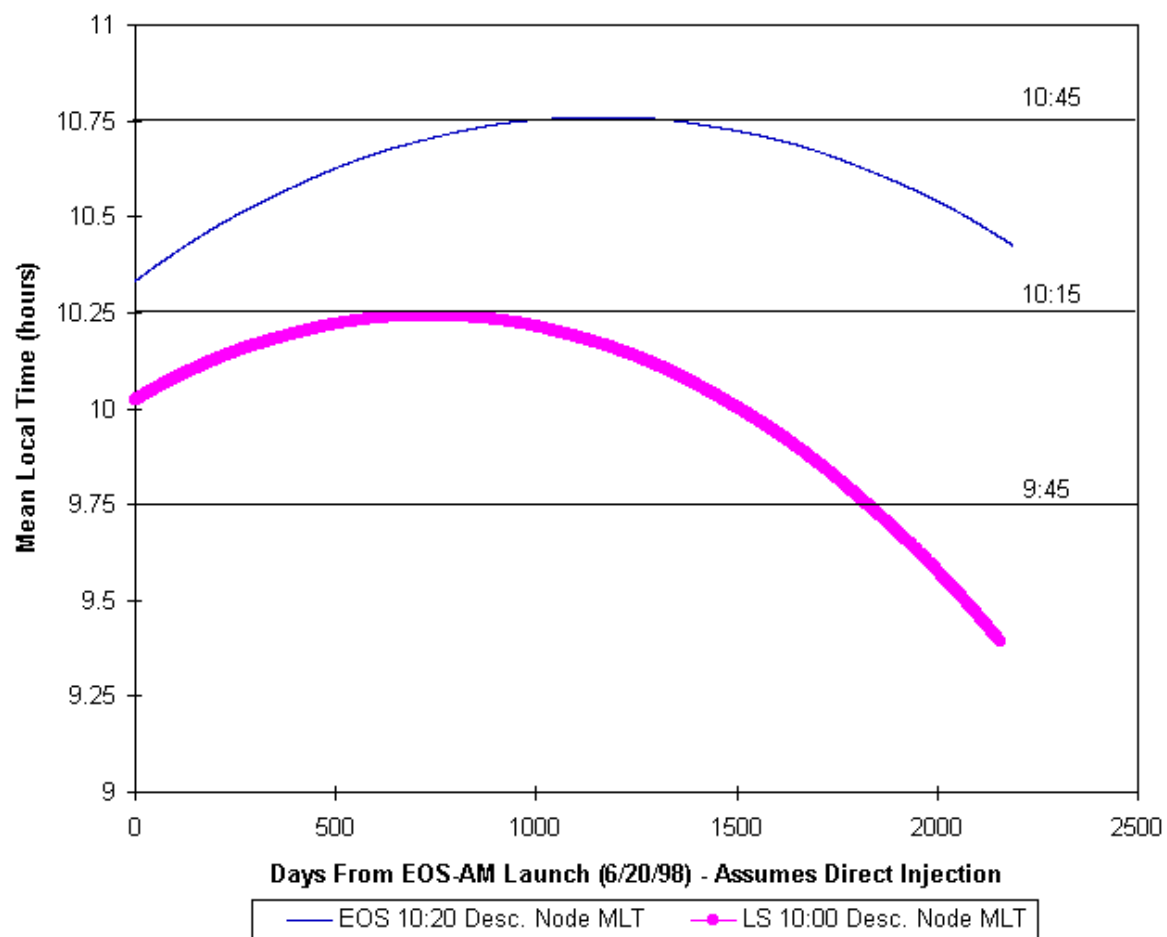
BACKUP SLIDES



Constellation Flying With Landsat 7 (Cont'd)



MEAN LOCAL TIME VARIATION FOR EOS-AM AND LANDSAT-7
Nominal Case





Constellation Flying With Landsat 7 (Cont'd)

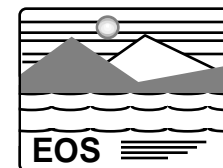


Table 1: Opportunities for EOS-AM1 to catch Landsat-7 During 30-Day Ascent Phase

| AM1 Injection Orbit Perigee | Mean Motion (°/min) | Relative Mean Motion (°/min) | Relative Mean Motion (°/orbit) | Relative Mean Motion (°/day) | Worst Case # of days to catch Landsat-7 | # of opportunities during 30-day ascent period |
|--------------------------------------|---------------------------|------------------------------------|---|---------------------------------------|--|---|
| 550 | 3.701 | 0.061 | 6.0 | 87.2 | 4.1 | 7 |
| 600 | 3.682 | 0.041 | 4.0 | 59.0 | 6.1 | 5 |
| 650 | 3.662 | 0.021 | 2.0 | 30.2 | 11.9 | 2 |
| 700 | 3.643 | 0.002 | 0.2 | 2.9 | 125 | 0 |
| 705 | 3.641 | 0.000 | 0.0 | 0.0 | N/A | 0 |

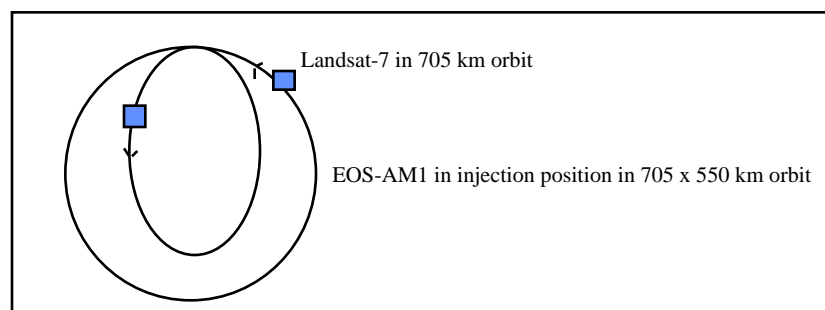


Figure 2(a): EOS-AM1 before Landsat-7

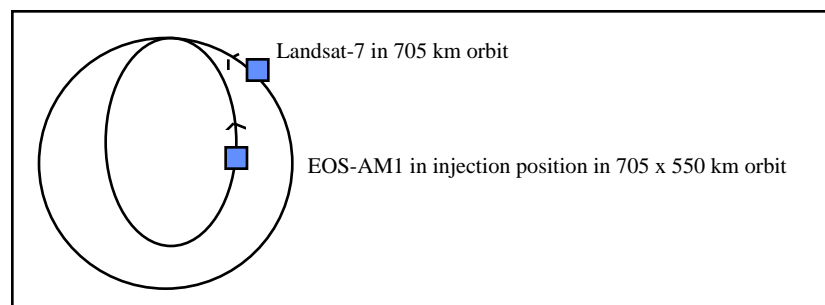


Figure 2(b): EOS-AM1 behind Landsat-7